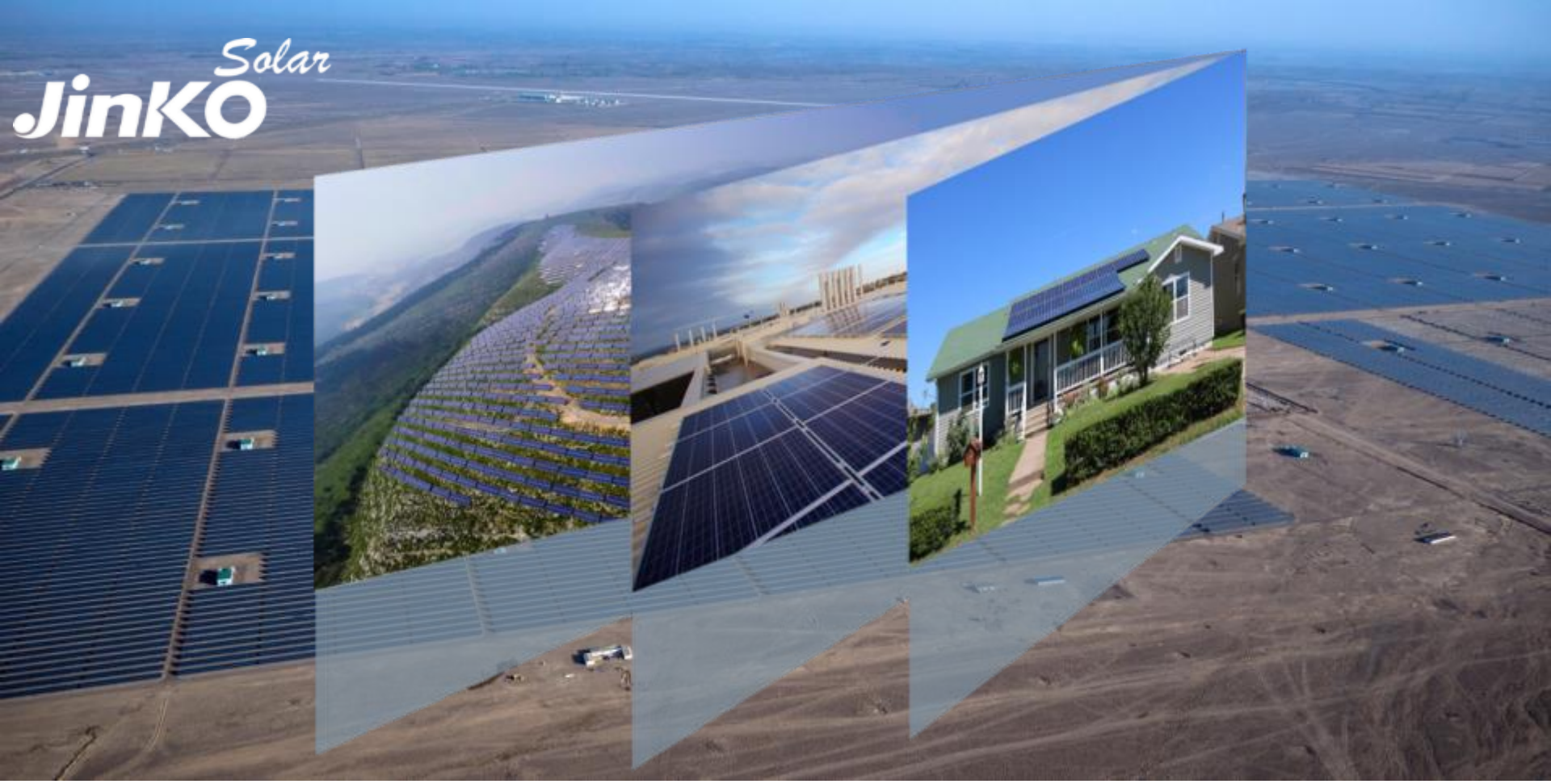


Reaching Higher Standards with Cell and Module Innovation

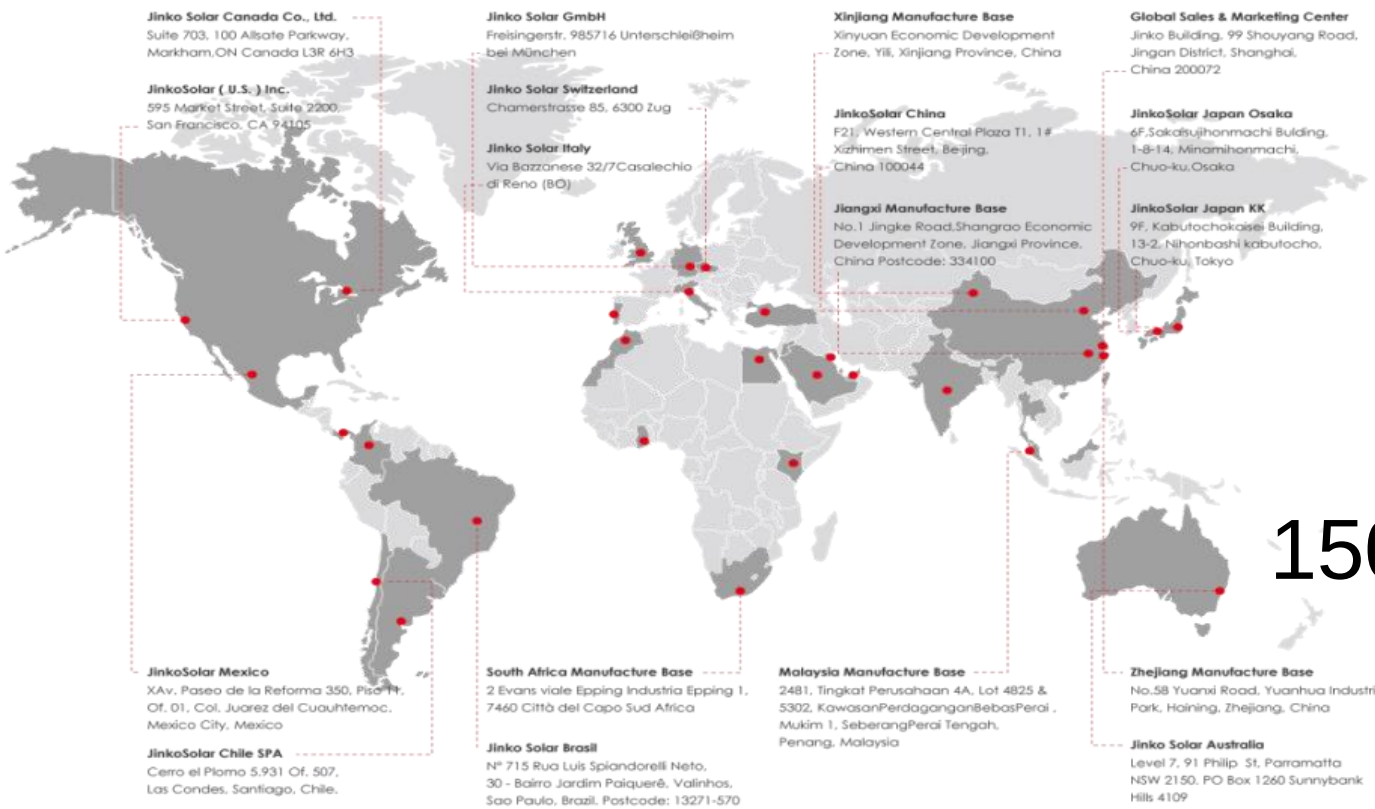
EU_PM Dept. 27 Mar ’18 ,

Andrea Viaro, Head of Technical Service Europe

Agenda

1. Jinko Solar Introduction
2. Technology Innovations from Jinko Solar
   - a. Mono PERC
   - b. Half-cell
   - c. Next-gen. Poly
   - d. Multi -Wire
   - e. Bifacial
3. Summary

Key Facts of JinkoSolar



8 Global Factories

31 Subsidiaries

80+ Countries

15000 Employees

9.5 GW | 26 GW

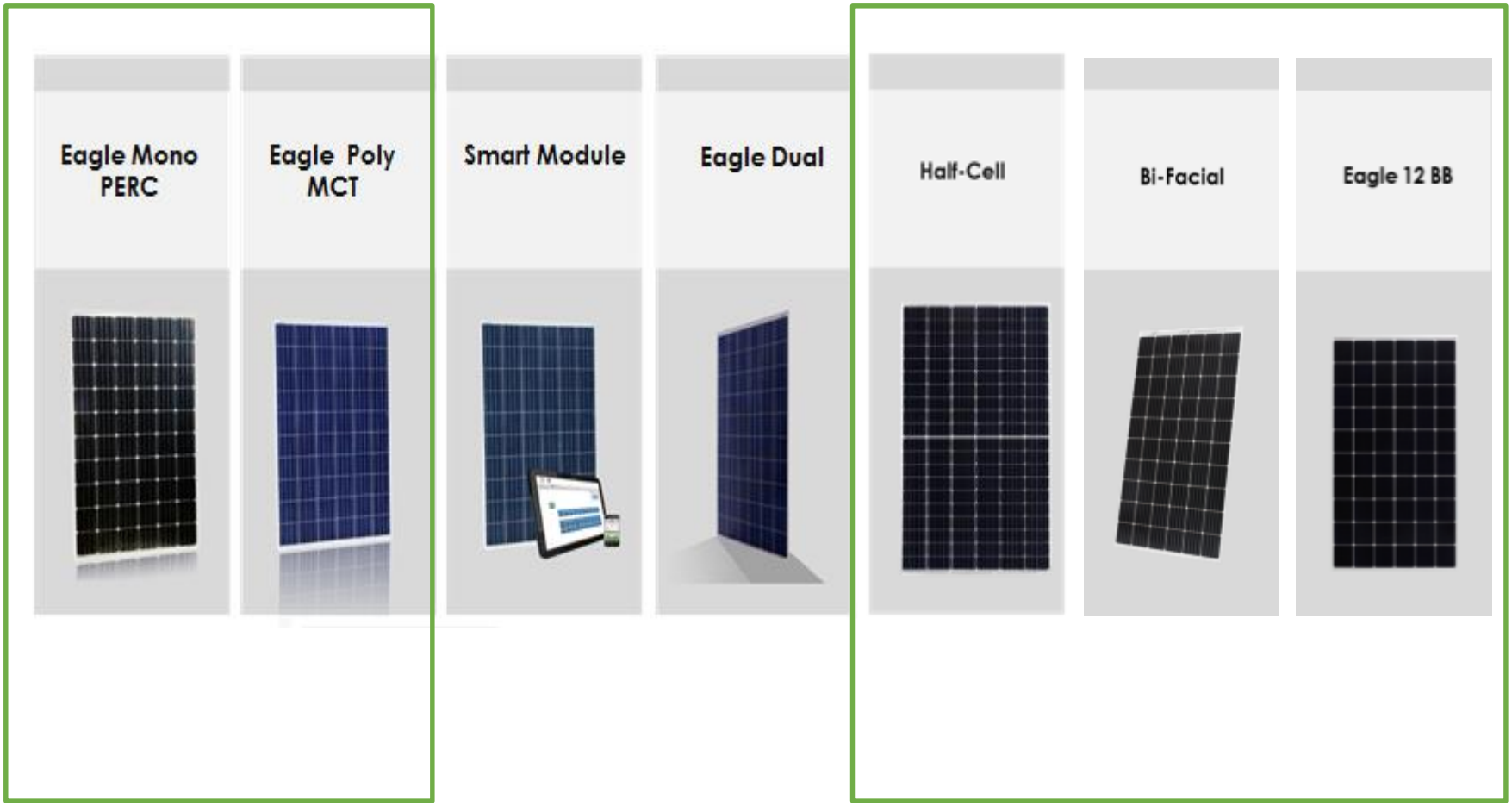
Capacity | Delivered (2017)

JinkoSolar R&D

State Key Laboratory

- Overall **328** full-time technical staff at Jinko Solar
- In-house R&D center for solar cell research: over **7,000 m²** with **7** separate laboratory rooms and over **100** research equipment
- Close cooperation with global research institutes
- Filed **464 patents**, authorized 232 (Till 2016)

Product Portfolio



Agenda

1. Jinko Solar Introduction
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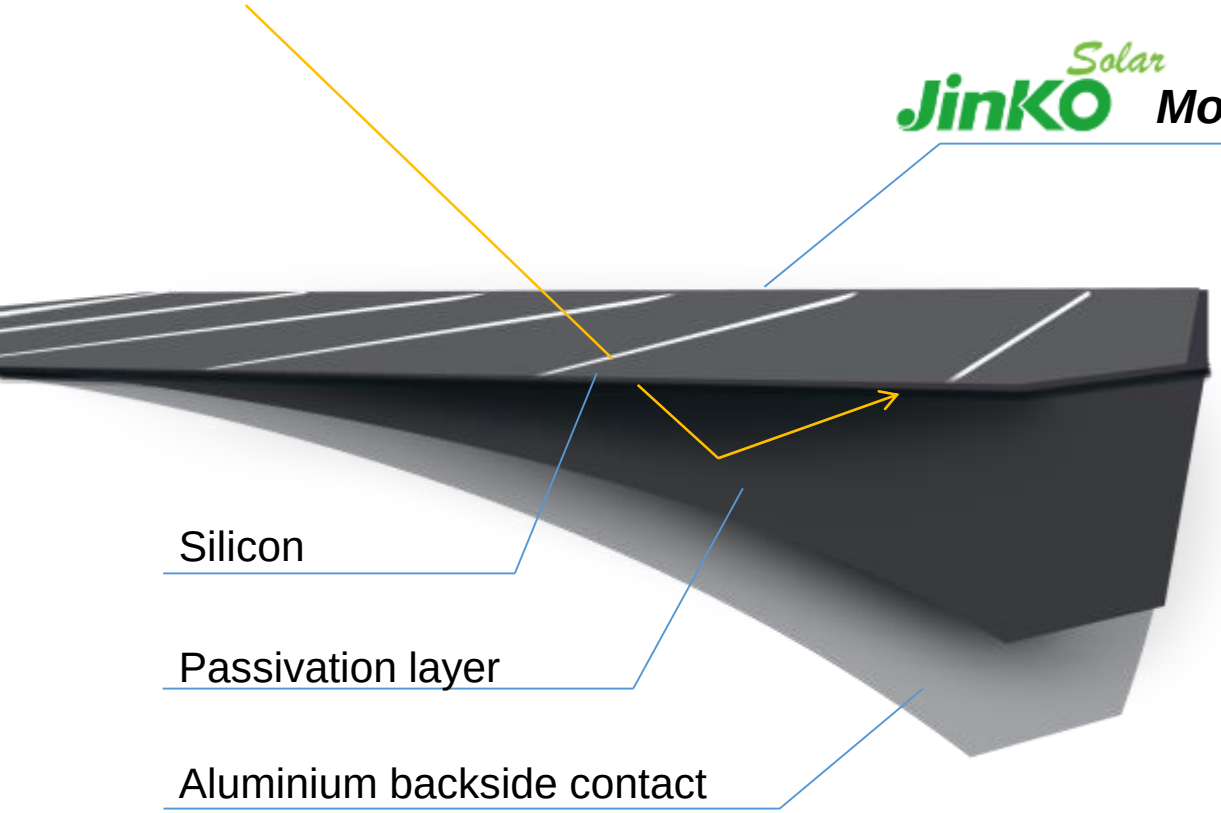
Mono PERC

Benefits of JinkoSolar Mono-PERC



JinKO Solar *Mono-PERC* technology

- Higher I_{sc} & V_{oc}
- Better IR response

+5%

Power

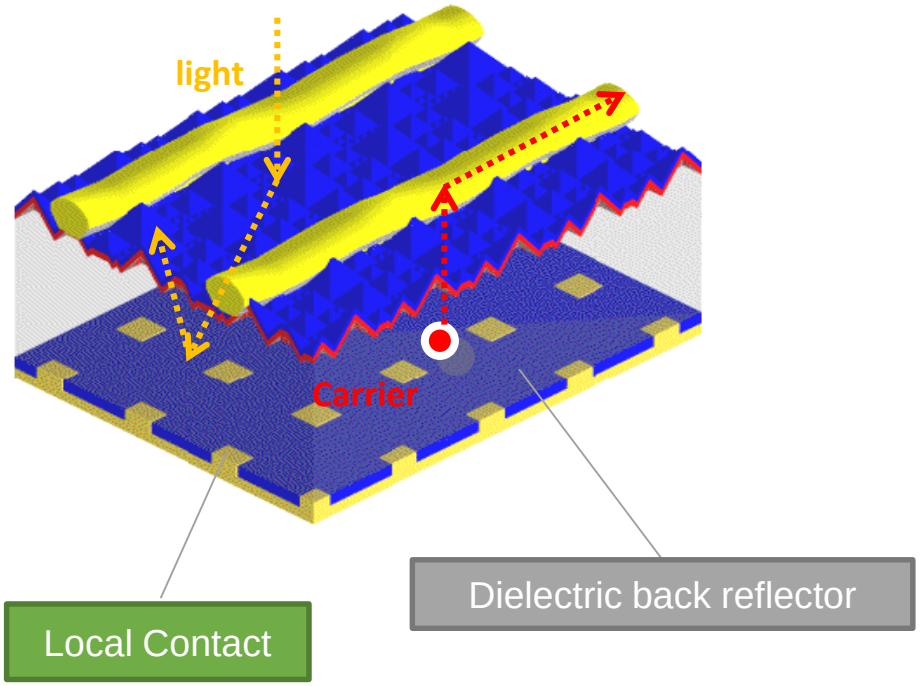
(Compared to Jinko Mono Standard)

Power Range:
60 cell 295~315
72cell 350W~370

Module Eff. boost >1%
Higher power density
(no space constrains)

Lower System Costs:
-7% transp.
-6% install.
-4% BOS

Mono-PERC (Passivated Emitter Rear Contact)



PERC cell Features

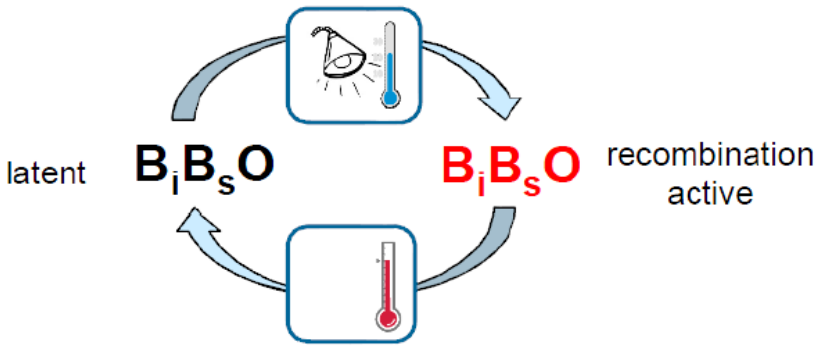
- Enhanced internal backside reflectance to capture more long-wavelength light
- Decreased rear current carrier losses by reducing the rear side recombination
- Higher Quantum Efficiency than conventional cells

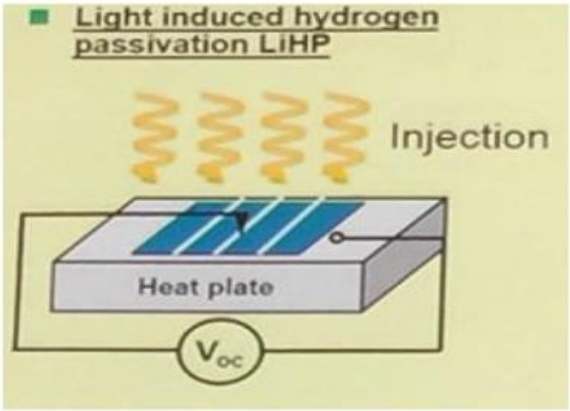
Main Advantages:

- The most cost-effective C-Si high-eff. leading technology
- Available at multi-gigawatt scale industrial production
- Mature technology and long track record
- Long-term established QA protocols during whole production
- High potential for further cell efficiency increase

Light Induced Degradation (LID) Solution

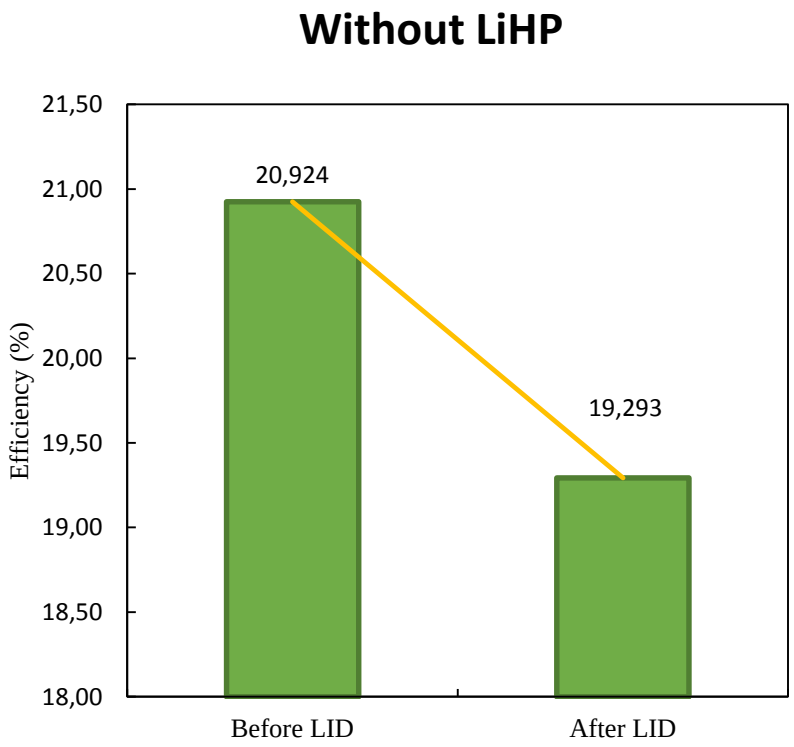
- Illumination of mono cz. P-type solar cells → Eff. reduction up to **5%** abs
- Main cause: recombination of active **Boron–Oxygen** complexes (B-O), especially in highly Boron-doped & Oxygen-rich silicon

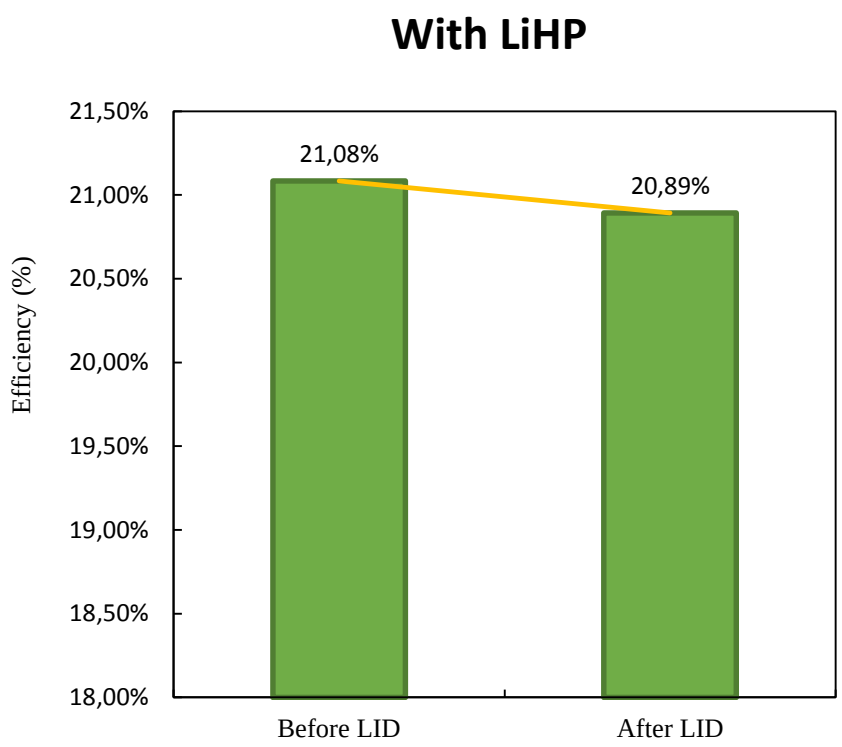




- **Light-induced Hydrogen Passivation** (LiHP) can dramatically reduce LID, i.e. regeneration process
- Key parameters to deactivate Boron–Oxygen complex (Passivation): Temperature, carrier injection, Hydrogen diffusion

Regeneration Effect



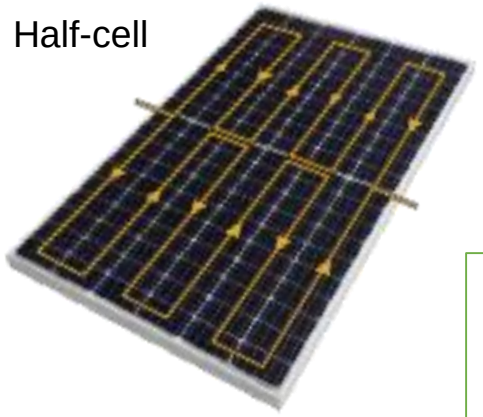


Testing condition
Irr 900-1000 W/m ^{2}
Cell Temp. 50-60℃
Light Soaking 5 hours

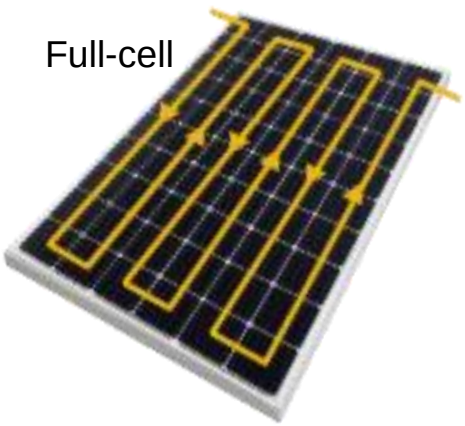
Half-cell

Half Cell: Technology

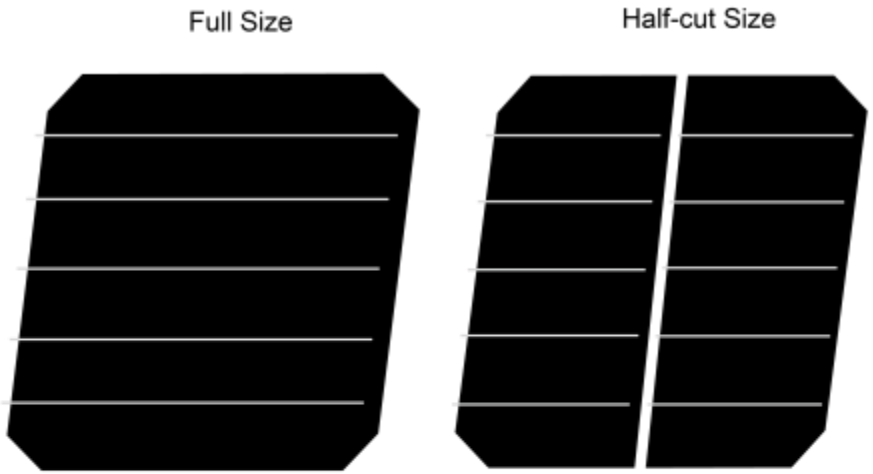
Half-cell

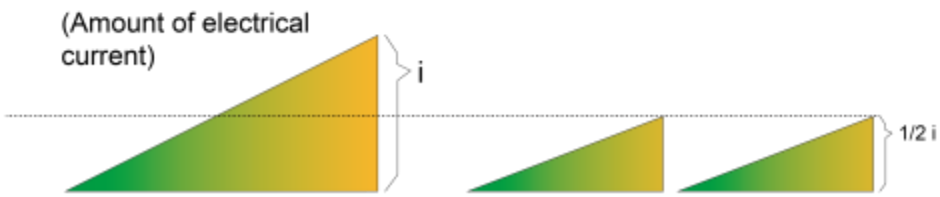


Full-cell



$$P_{loss} = I^2 * R_s$$

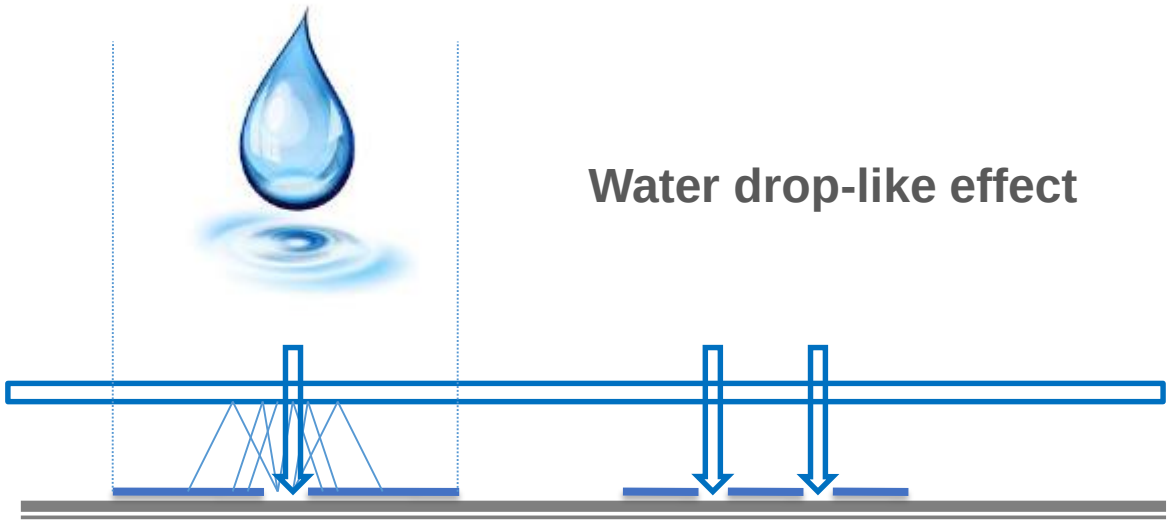




Electrical current (i) flowing on busbar is halved

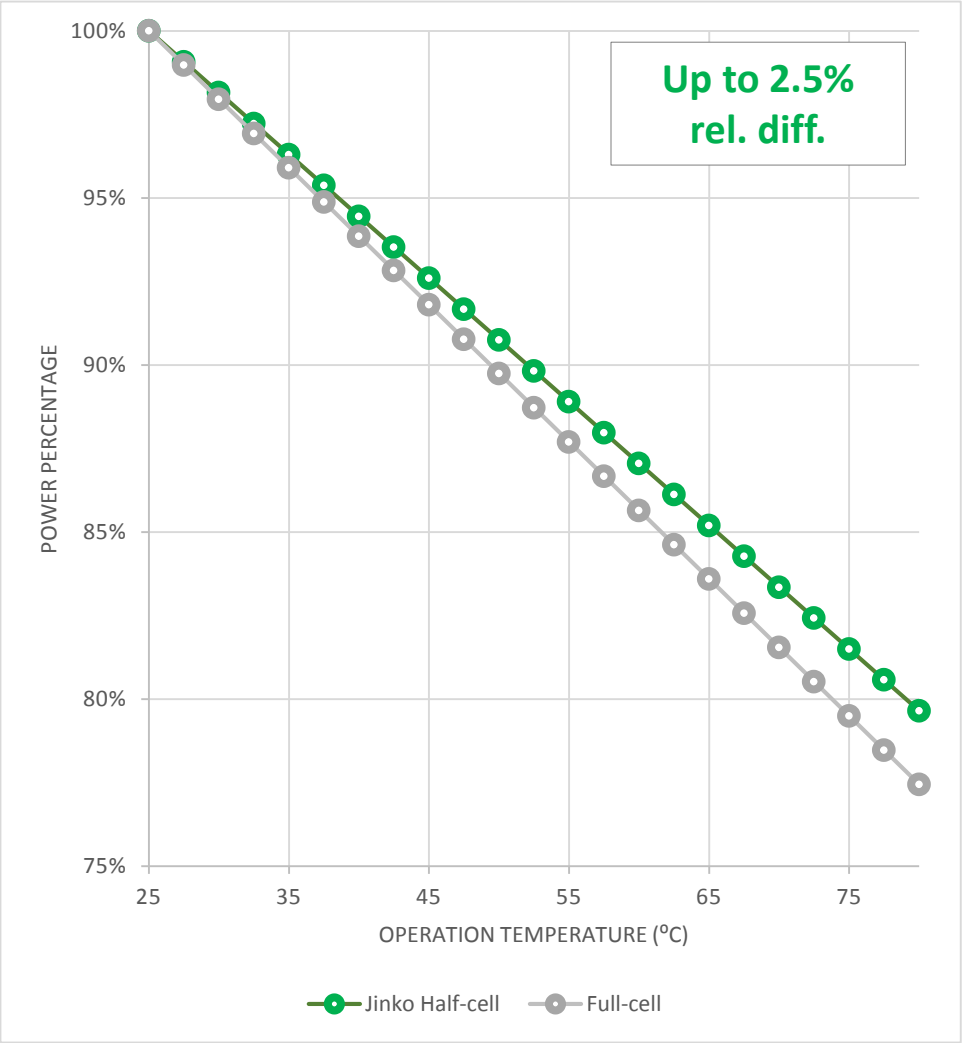
Resistive losses in a HC module is ¼ of a full-sized cell

Half-Cell Module Higher Light Utilization



Larger overall "white" area → Increased inter-cell reflecting area → Increased internal reflections → Higher light absorption

Advantages from HC Modules – Temperature Coefficient



Significant Temp. Coeff. improvement

Same nameplate power

280 Wp Mono-Si Module

Op. Temp.: 65 °C

Conventional → -0.4% → 235Wp

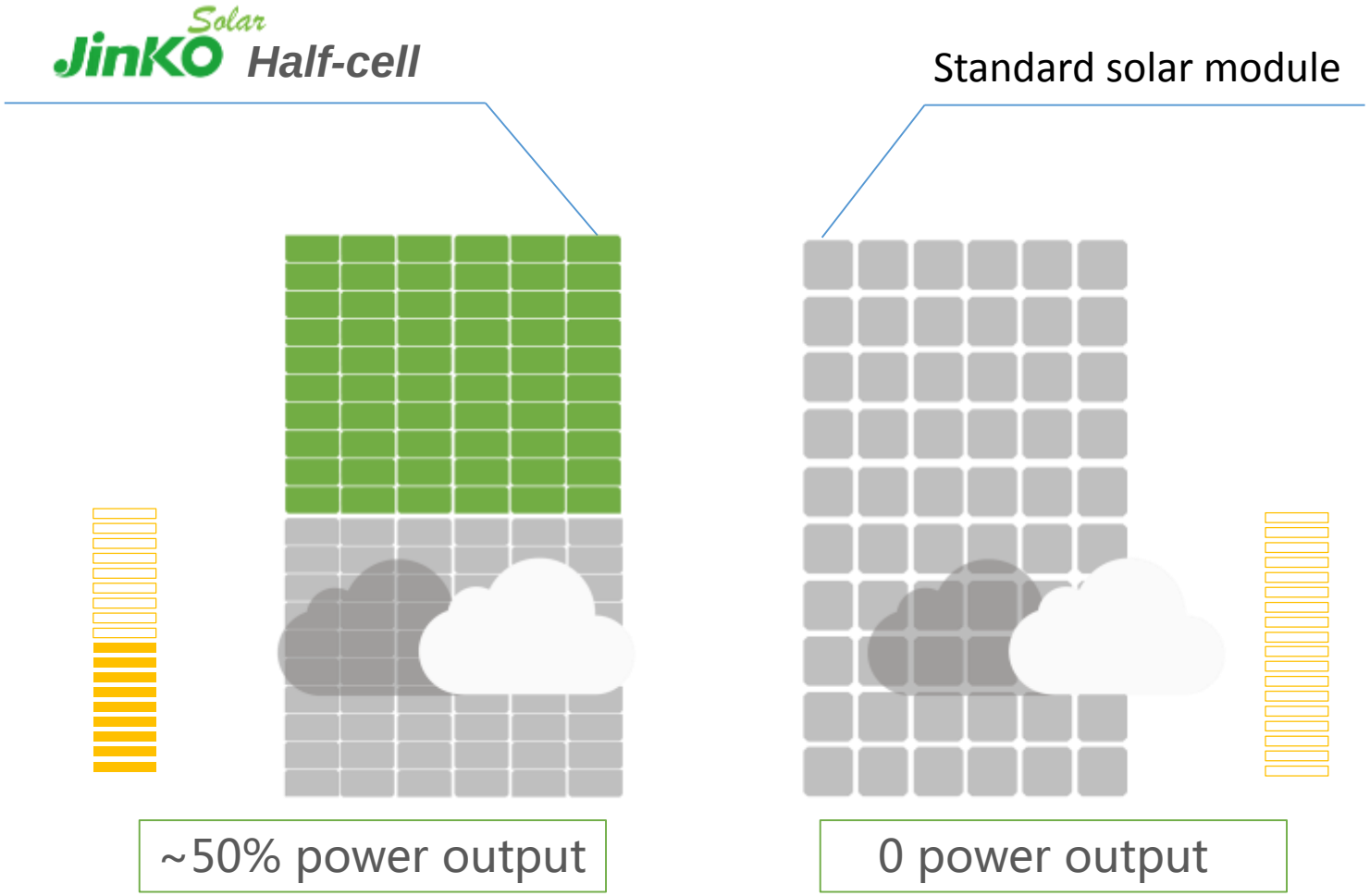
Half-cell → -0.37% → 240Wp

Difference > 2% rel

Superior Power Generation

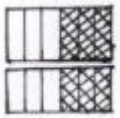
at Higher Temperatures

Better Mismatch & Shading Mitigation

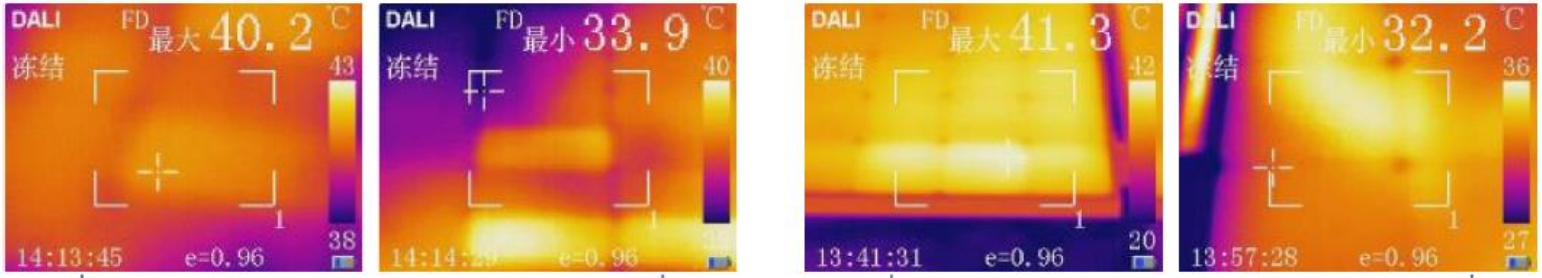


Lower shading losses of HC compared to normal module, in certain shading conditions

Lower Hot-Spot Level, Despite Higher Wp

Cell	Shading condition	Maxim temperature from test	Delta
Mc-Si	 ½ cell	115.4	/
	 ½ half cell	96.0	19.4
Mono PERC	 ½ cell	122.4	/
	 ½ half cell	98.0	24.4

- Current, thus Power of half-cell is halved
- Lower Power dissipated on shaded cell
- Around 20°C lower temp. In hot spot test
- Less risk for system operation

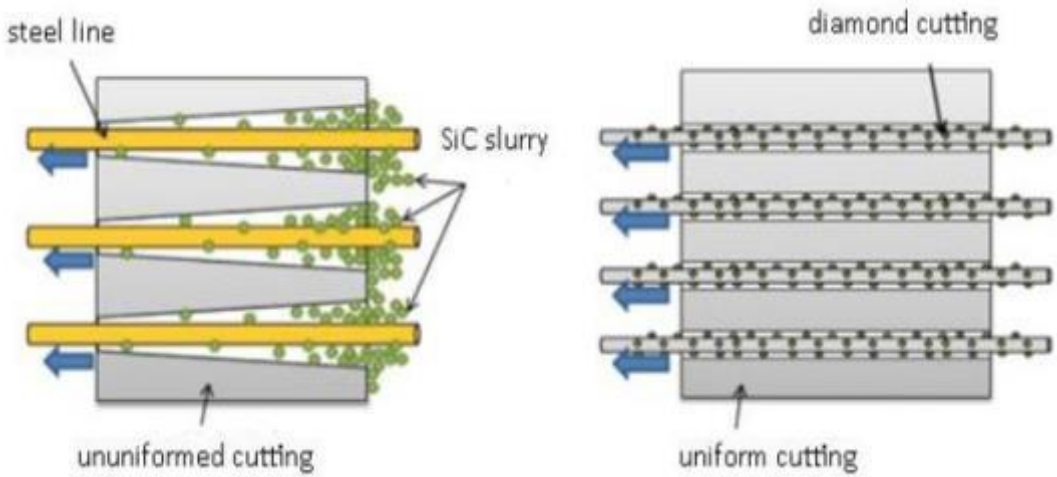


Half-cell

Full-cell

Next-gen. Poly

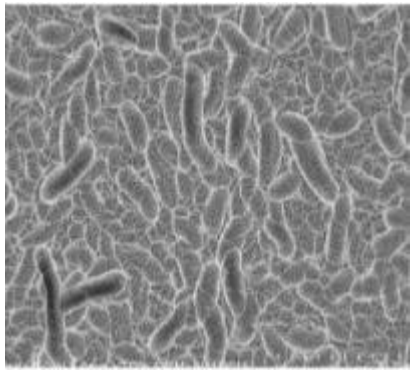
Green/Efficient Wafer Production Tech.



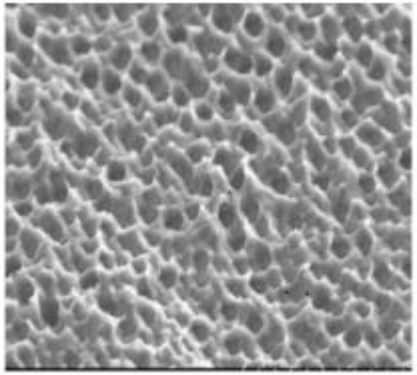
- Diamond cut leads to less waste material
- Dark-grey colour appearance → Improved light absoption
- Uniform cutting → More even and precise thickness of wafer
- Less damages on wafer surface (cracks, etc.) → Higher reliability
- Faster process, which consumes less energy and therefore is a ‘greener’ cell

Diamond-Wire Cutting + Metal-Catalyst Texturing (MCT)

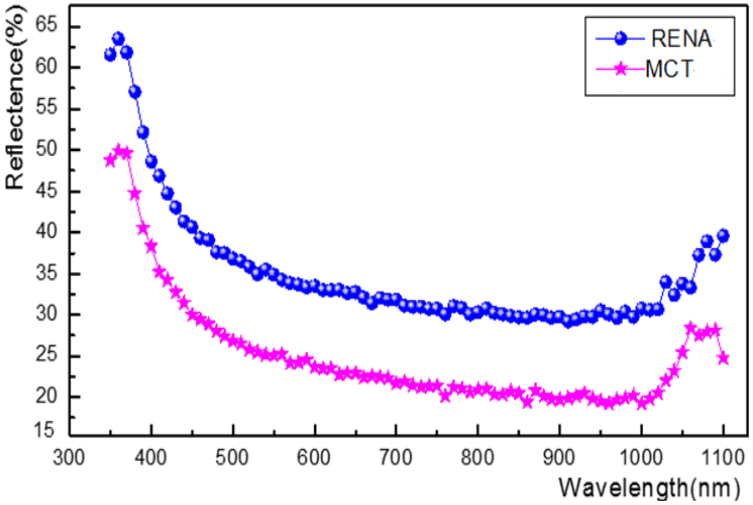
SEM Photo



Conventional Technology



MCT Technology



Lower reflectance

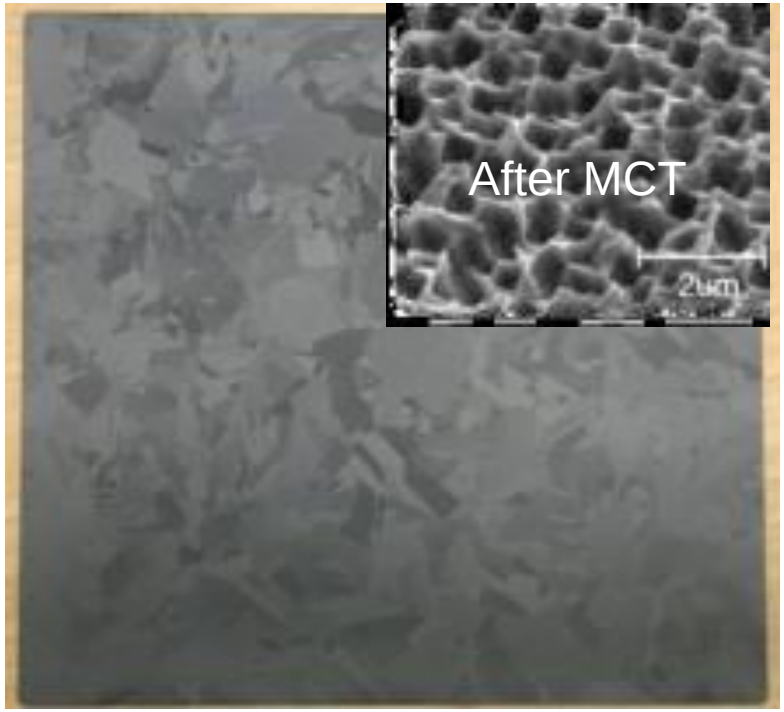
→ boosted light utilization

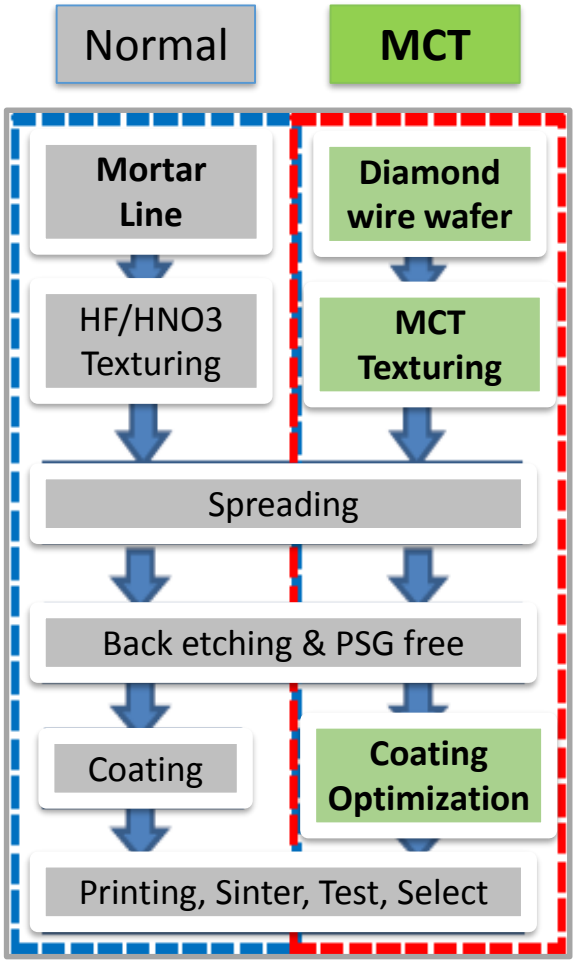
Applied to **diamond-wire sawing** wafers

Module power output increased by **2W~3W**

MCT: Metal Catalyzed Texturing

MCT Theory:
Silicon is textured by Ag as catalyst, and optimized coating process

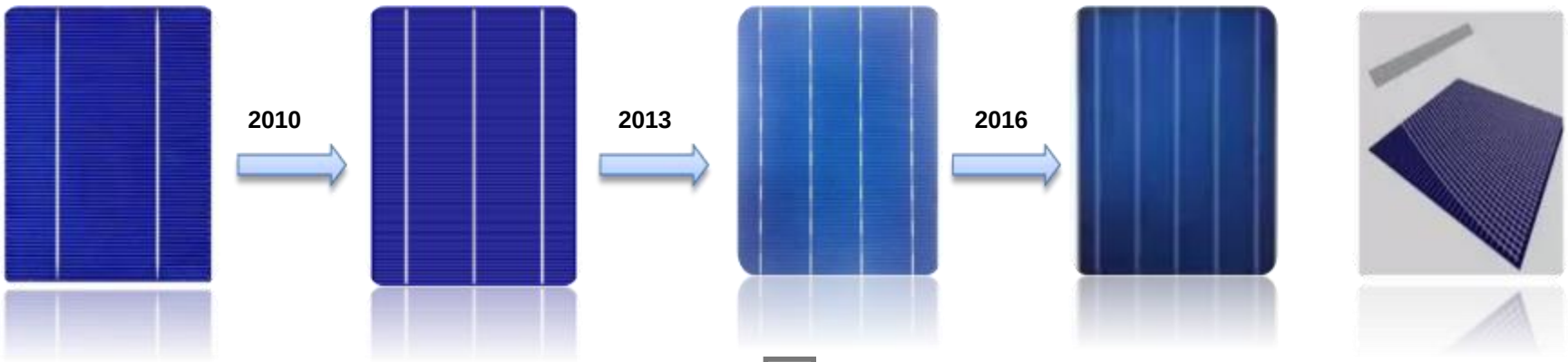




Multi-wire

MBB: Module Busbar Evolution

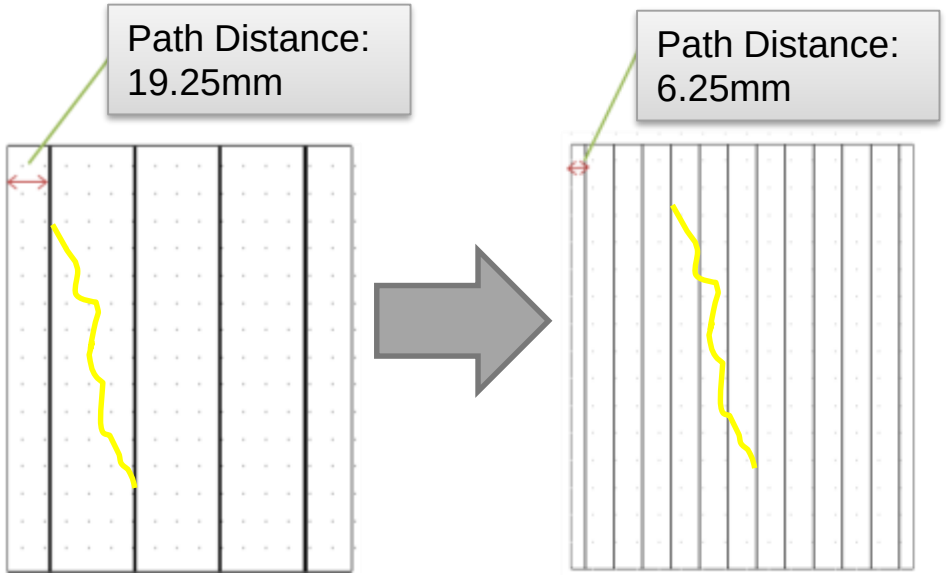
Busbar Number trend



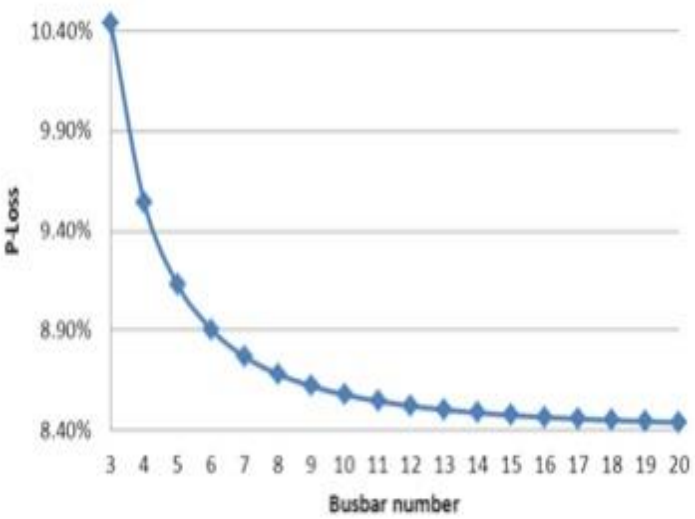
2018 MBB

MBB: Lower Loss

Lower current path distance

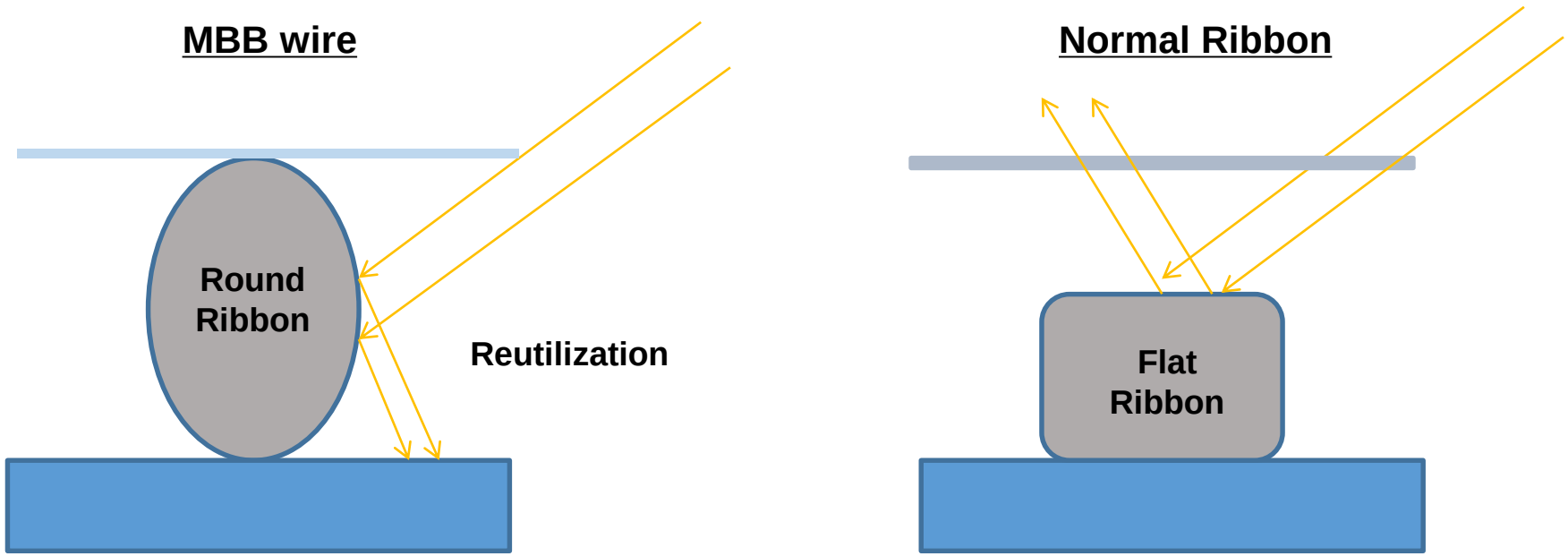


Power loss VS. Busbar Number



Compared to 4BB, power 12BB is around **3W higher**

MBB: More internal reflection from round ribbon

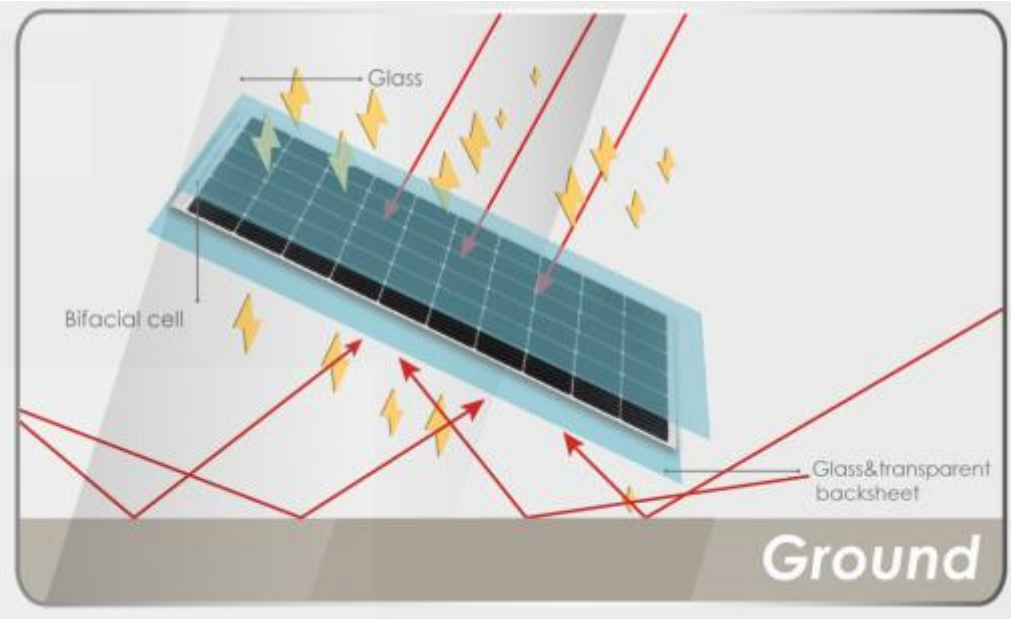


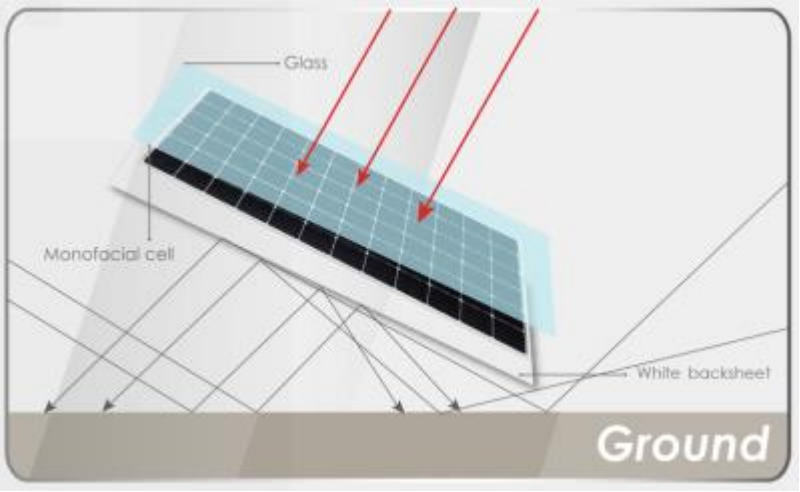
3rd party data, power of MBB module is around 1% higher

Bifacial

Standard Modules vs Bifacial Modules

With optimized PV system design, Bifacial module can generate up to ***20~30%*** more energy compared to conventional monofacial module



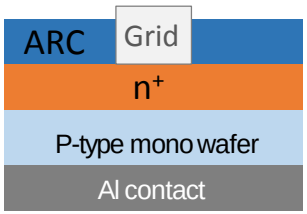


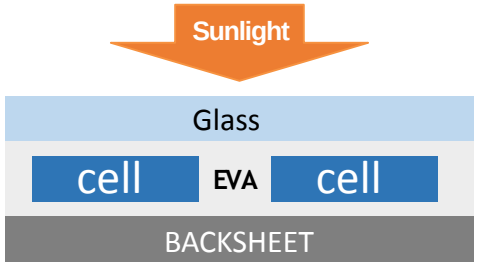
Bifacial module: double-sided generation

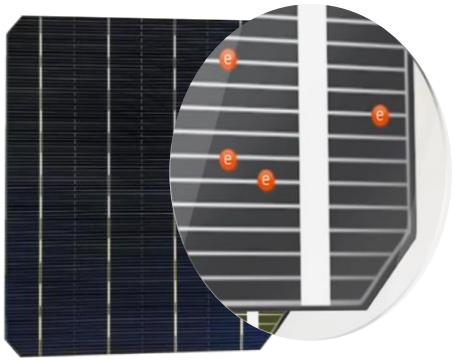
Standard module: front-sided generation

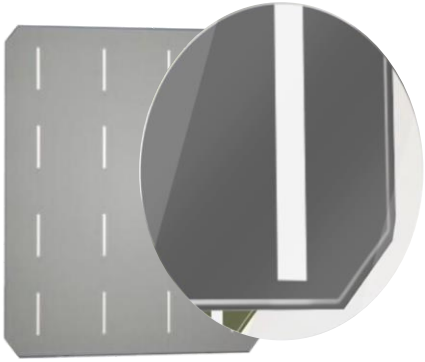
BiFacial: Tech. Concept

Conventional





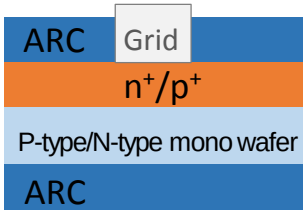


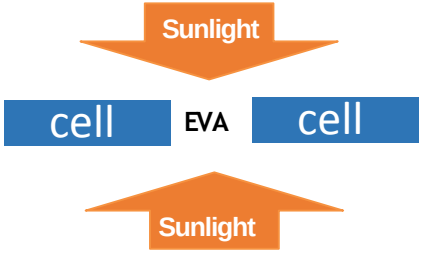


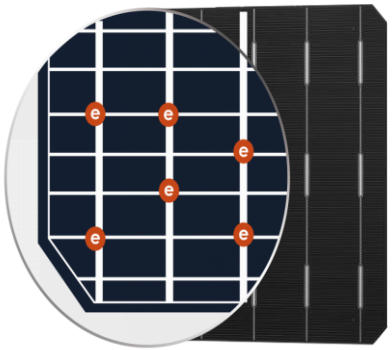
Front Side

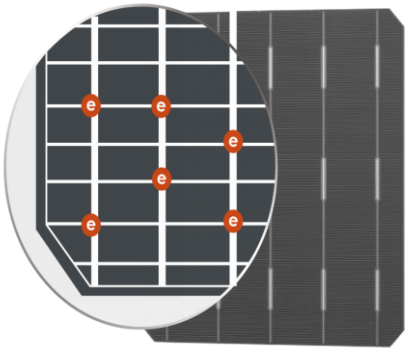
Back Side

Bifacial









Front Side

Back Side

Benefits of JinkoSolar Bifacial

Save Module and BOS Cost

Assuming that two solar farms generate same amount of energy (1,414 MWh per yr),
Jinko solar Bifacial farm can save BOS costs including land area,
compared to single-face P-type

260W P type single-face module
2,743ha

300W JinKO Solar ***Bifacial***
2,407ha
(Assuming max rear-sided generation 27.3%)

Agenda

1 Jinko Solar Introduction

2 Technology Innovations from JinkoSolar

- a Mono PERC
- b Half-cell
- c Next-gen. Poly
- d Multi -Wire
- e Bifacial

3 Summary

Summary

- Next PV module generation will be a combination of different technologies at both Cell and Module level

- Mono PERC is at present the most cost-effective C-Si high-eff. leading technology that is best used at multi-gigawatt scale industrial production

- HC modules currently present the most advantageous cost-benefits balance
- At least 1 higher power bin compared to the standard technology and improved Temp. Coeff.
- Even 2 classes higher if combined with other add-on features, such as White EVA+LRF

- Multi Bus Bar (MBB) is the next evolution of traditional busbar-based technology
- Module power is boosted by about 3W and reliability is also improved

- Bifacial module offer the highest potential for reducing LCOE
- With optimized PV system design, 20~30% more energy can be generated compared to conventional single-face module

More information can be found on our Website

Company Profile

Datasheets

Product Certificates

Factory Certificates

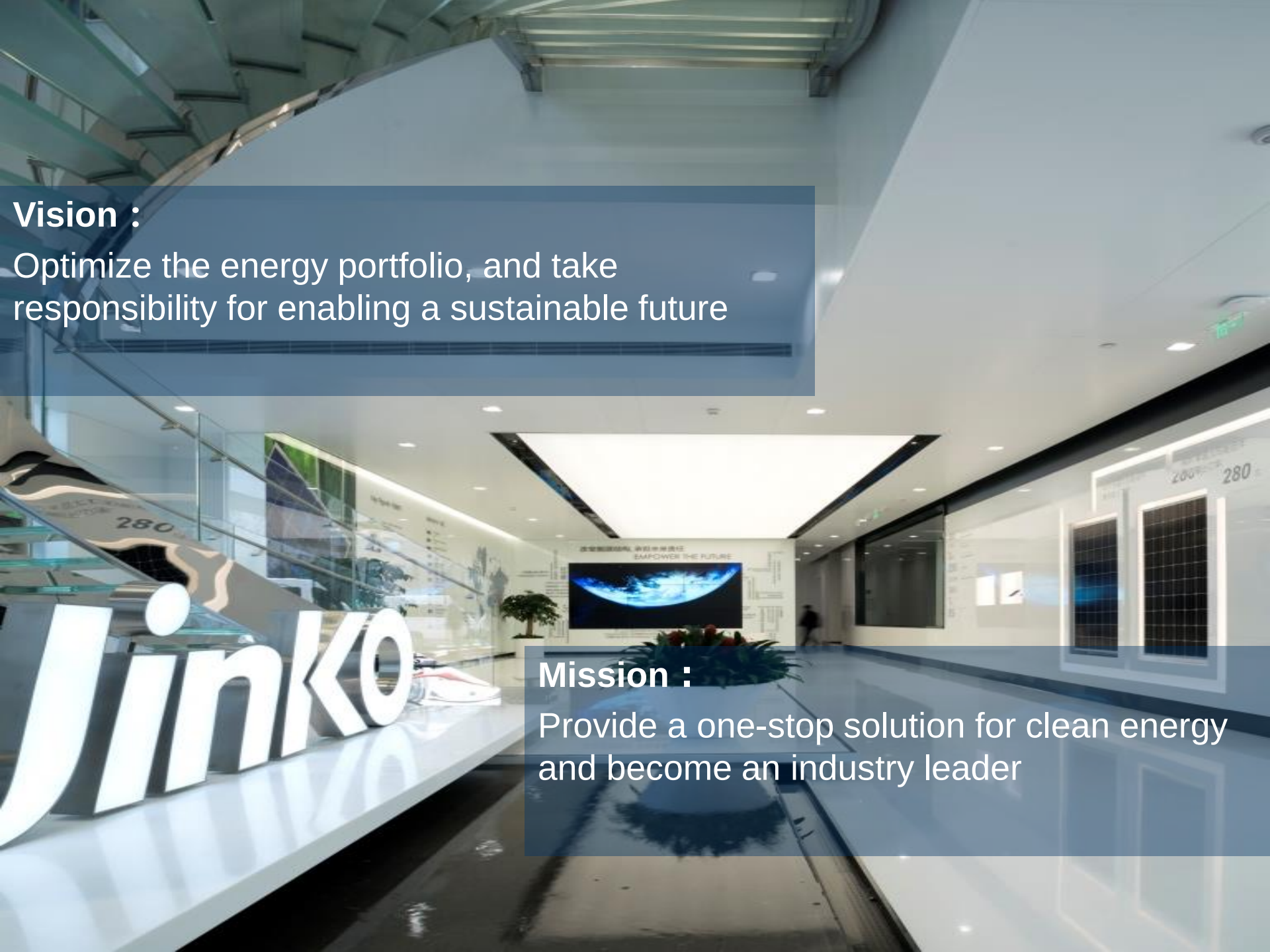
Installation Manual

Warranty

www.jinkosolar.eu

Thank you!

Back Up Slides



Vision：

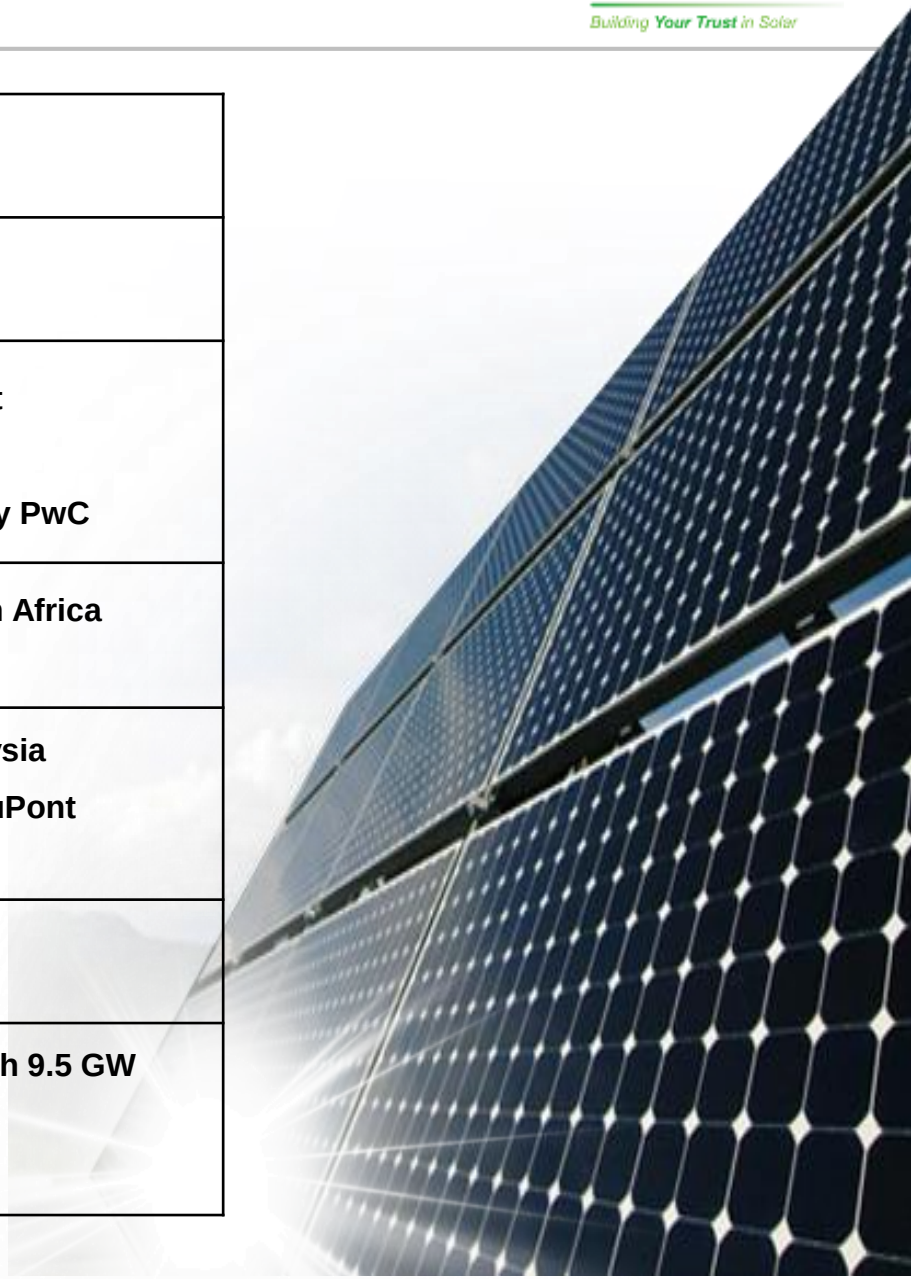
Optimize the energy portfolio, and take responsibility for enabling a sustainable future

Mission：

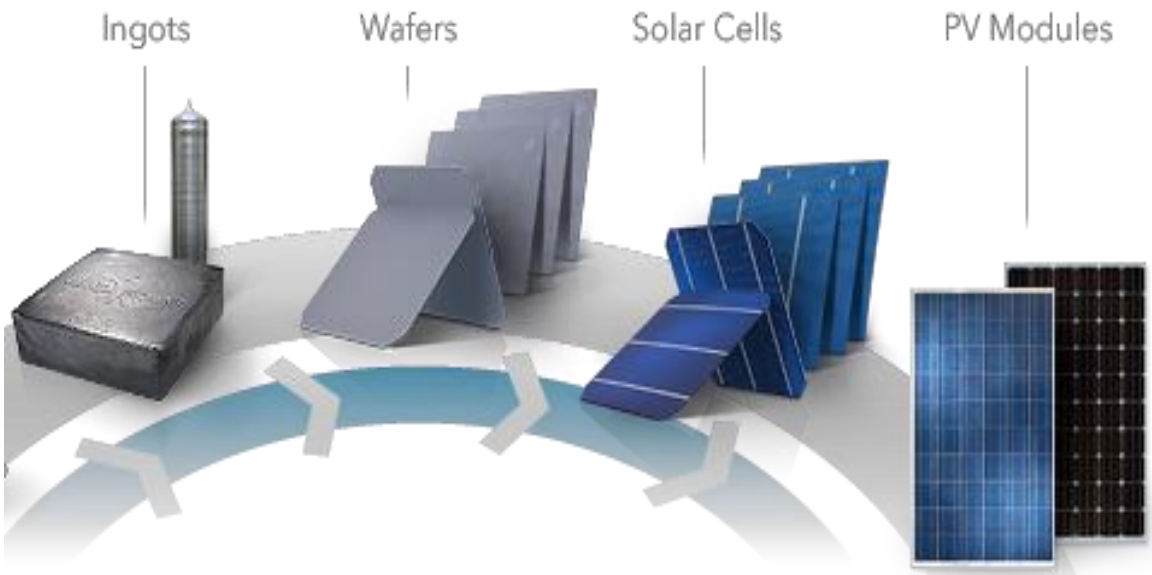
Provide a one-stop solution for clean energy and become an industry leader

Major Milestones

2006	• JinkoSolar Co., Ltd. established
2010	• Listed on New York Stock Exchange
2012	• World First solar company passing 85-85 PID test • Ranked No.2 in Photon Lab Test • Rank No. 4 in the PV Sustainable Growth index by PwC
2013	• Launched module manufacturing facility in South Africa • Reached > 6 GW shipments
2015	• Launched module manufacturing facility in Malaysia • Signed strategic collaboration agreement with DuPont Photovoltaic Materials
2016	• Bankable with over 58 major international bank
2017	• Largest producer of solar modules worldwide with 9.5 GW capacity per year



Vertically- Integrated Production

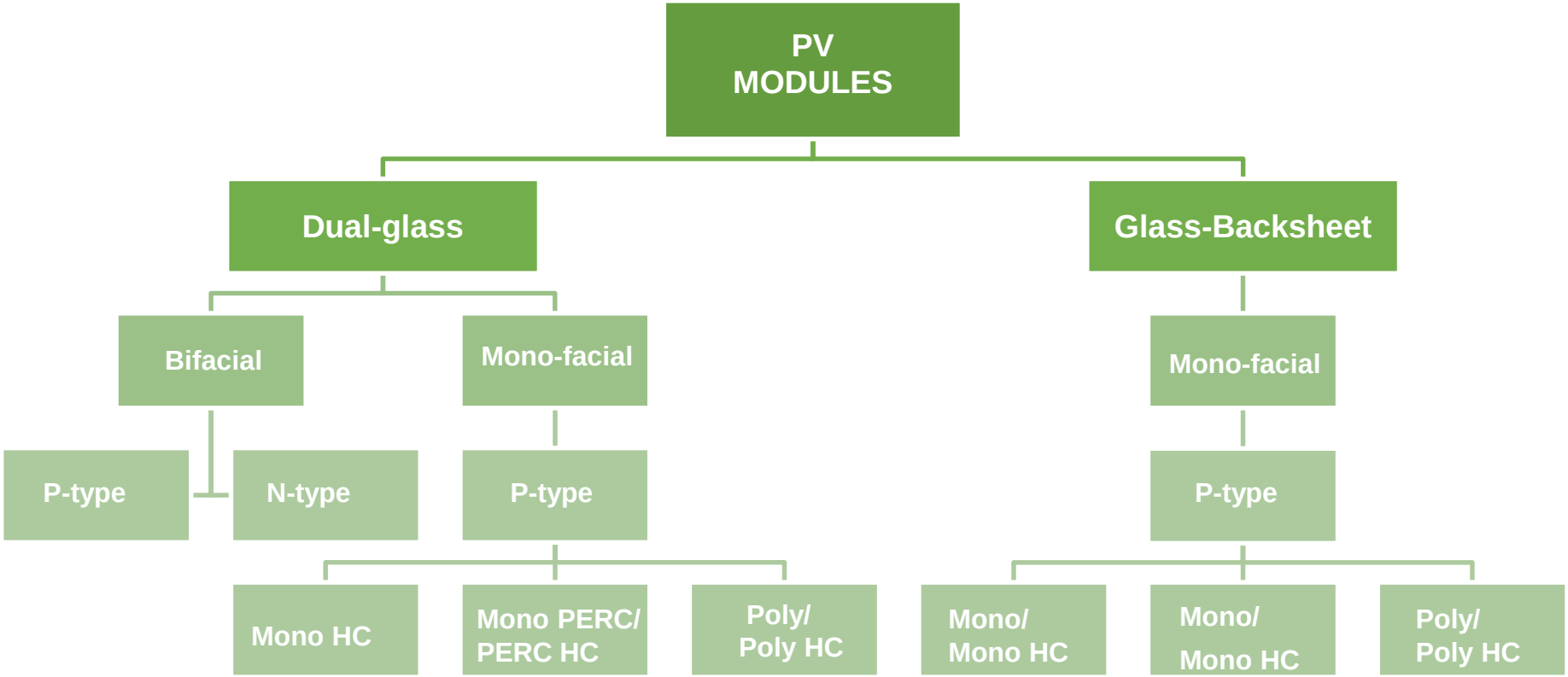


Quality Guaranty along the complete value chain

Ideal supply chain mgmt. with top-class components

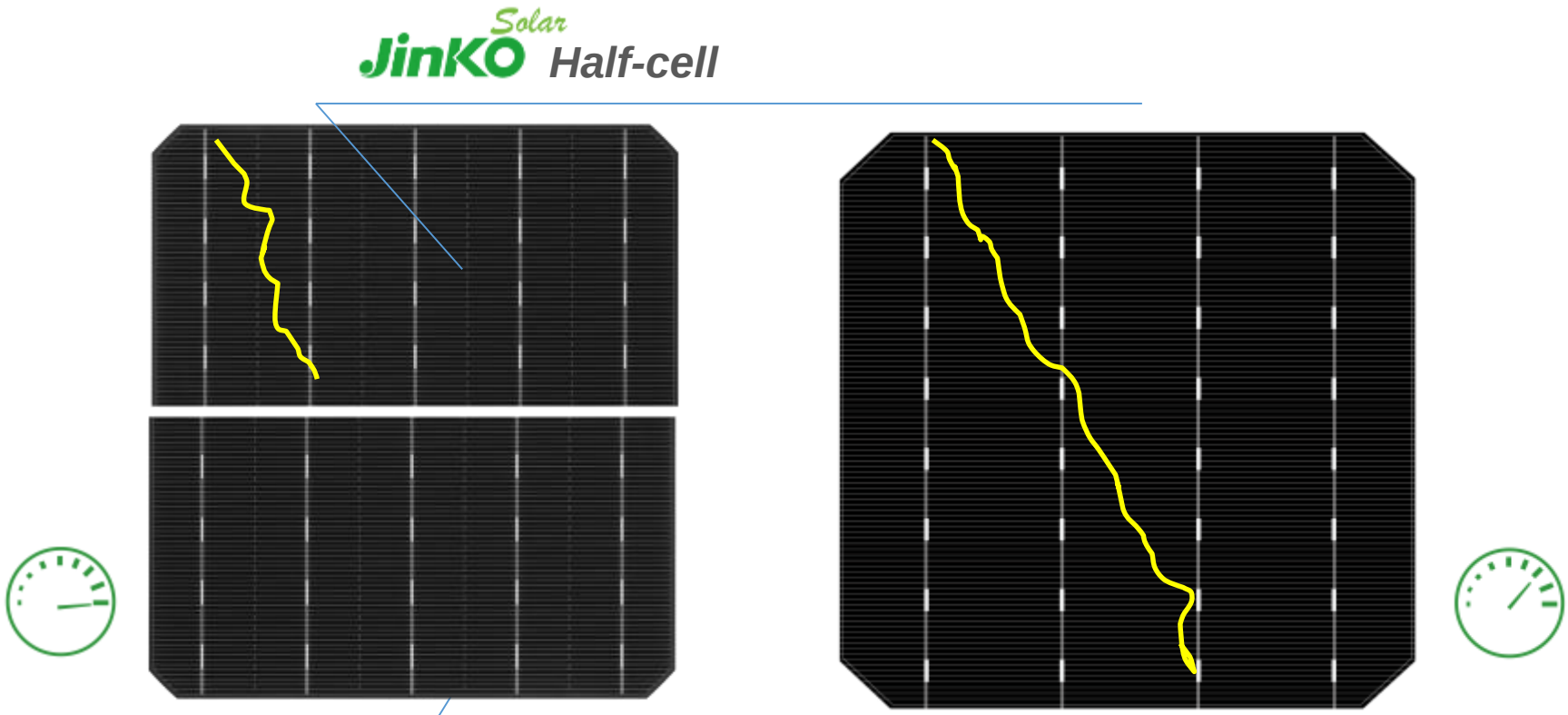
Optimized cost structure with 10 years of experience

Diversified Module Portfolio



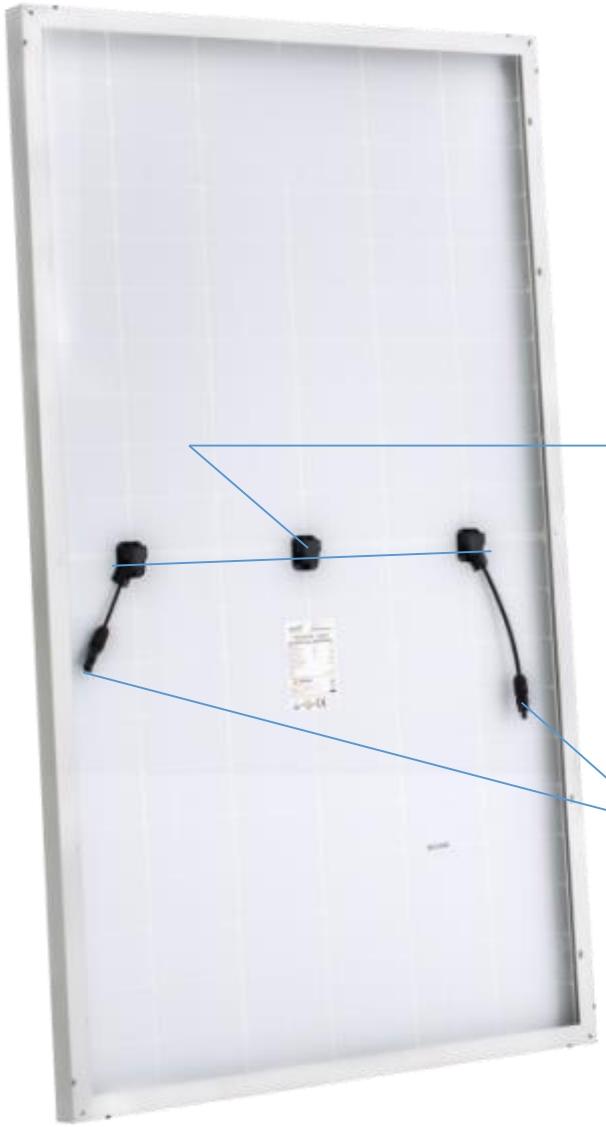
*** Multiple combinations of different cell tech., module type, add-on solutions**

Reliability and Micro-Crack Impact Mitigation



Smaller cell area reduces the potential impact of micro-cracks

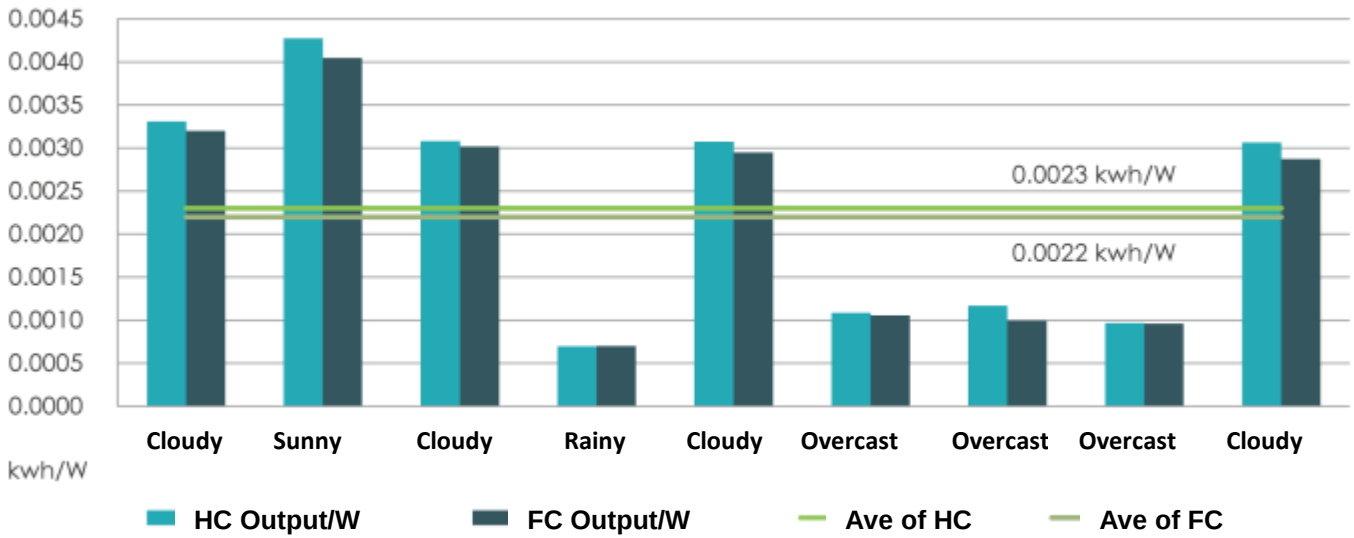
Lower JB Operating Temperature



Innovation decentralized junction box for improved heat management and simple connection

Anode 290mm, Cathode 145mm
or Customized Length

Higher Energy Output



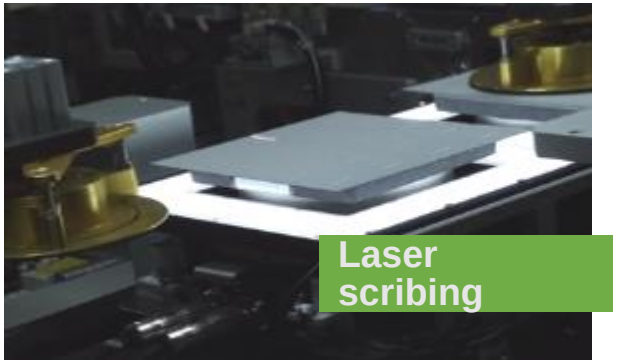
From Jinko R&D PV system based on apple-to-apple comparison

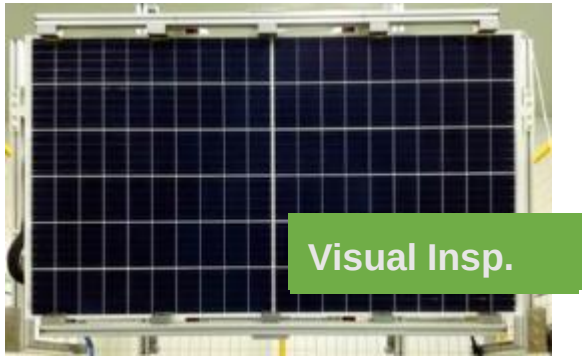
~4% more energy

Note: Power output is affected by environmental conditions

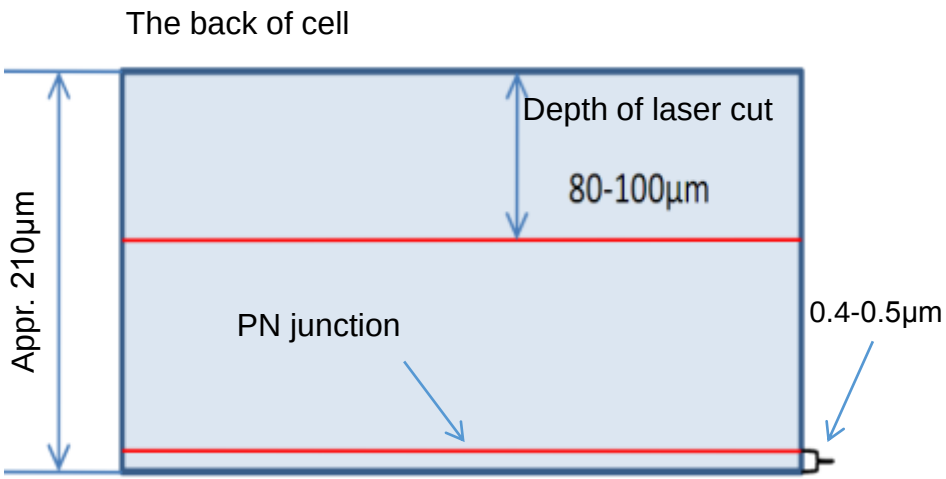
Half-cell: Production Process

State-of-art Technologies

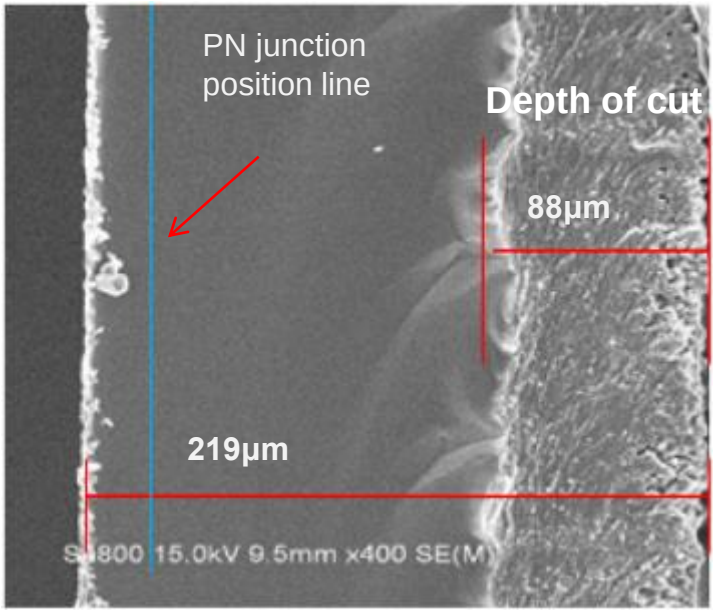




High Reliability : Optimized Laser Scribing



The profile of Half-cell

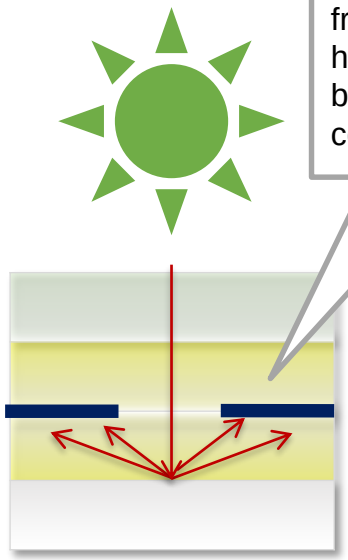


Back side

The SEM profile of Half-cell

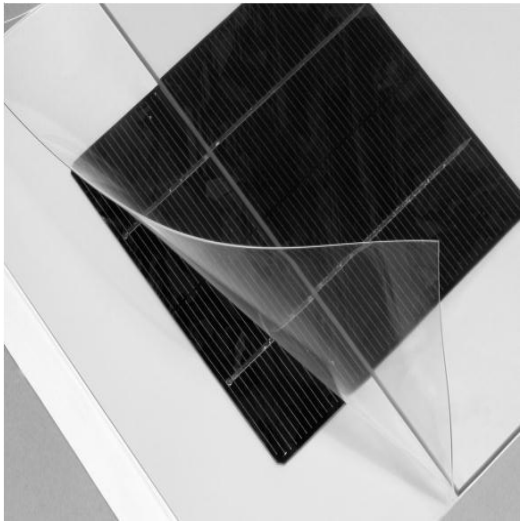
- The laser cuts from the back side of cell
- Depth of cut is about 40-50% of the cell's thickness
- Position of PN junction from the front side of cell is about 0.4-0.5μm
- Smooth area near the front side of cell, rough region affected by laser burning
- Distance between PN junction and laser cut area avoids damages to PN junction

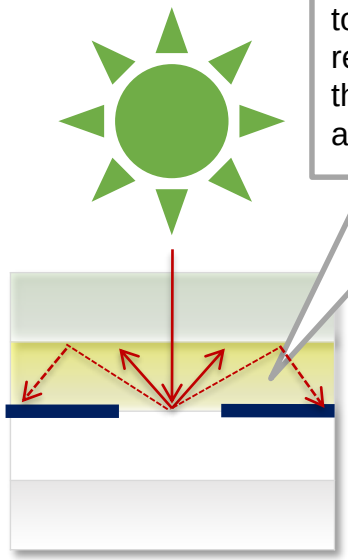
White EVA



Light is reflected from the backsheet has little chance of being absorbed by cell!

- **Glass**
- **Transparent EVA**
- **Cell**
- **Transparent EVA**
- **Back-sheet**





White EVA increases total internal reflection. Increasing the total light absorbed!

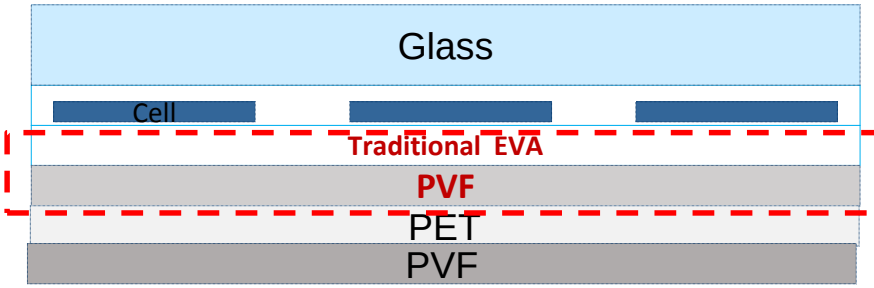
- **Glass**
- **Transparent EVA**
- **Cell**
- **White EVA**
- **Back-sheet**

White EVA increases power thanks to internal light reflection (water- drop effect)

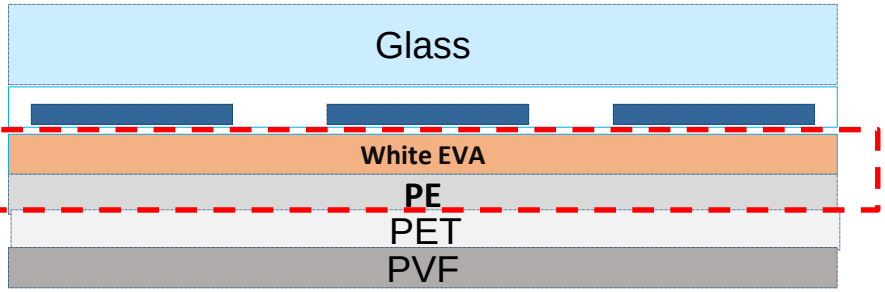
Up to 2~4W power increment(confirmed by internal tests)

TPE + White EVA

Traditional TPT Solution



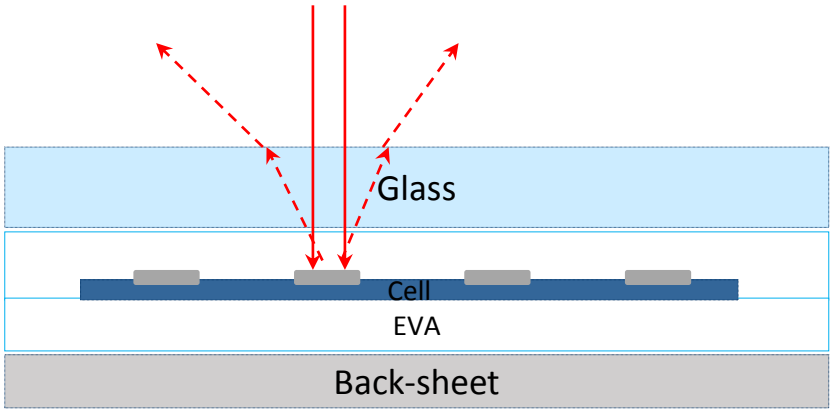
Improved TPE + White EVA Solution



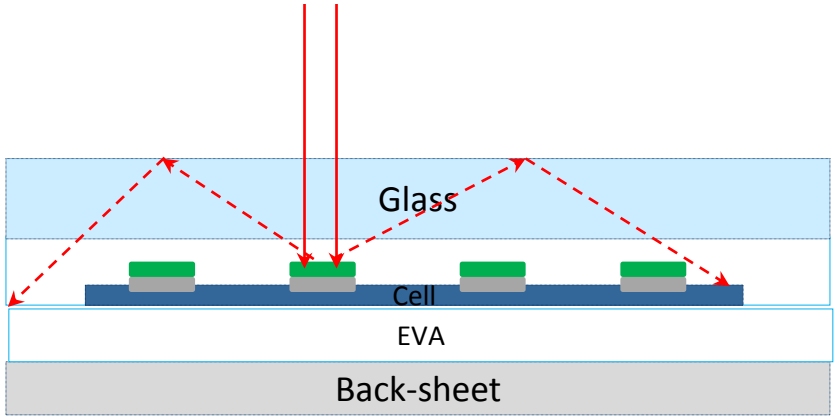
	Yellowing Index (UV)	UV Block Ability (T%)	WVTR
TPT + Traditional EVA	6	0.012%	2.6
TPE + White EVA	**0.88**	**0.010%**	**2.01**
Test purpose	432 KW.h/m^2 UV irradiance =30 times higher than natural conditions to simulate 25y aging in hash environment	Evaluate backsheet ability to protect the PET layer from UV light	Protection ability against moisture ingress into the laminate
Results	More than 10 times lower UV index → lower material aging	PET core exposed to only 0.04kW.h/m^2 UV in 25y	20% better WVTR

Light-Redirecting Film (LRF)

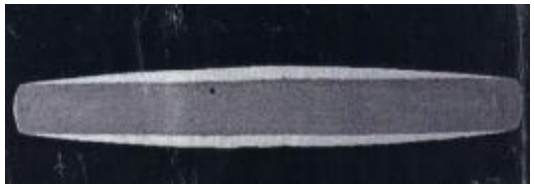
Traditional Ribbon

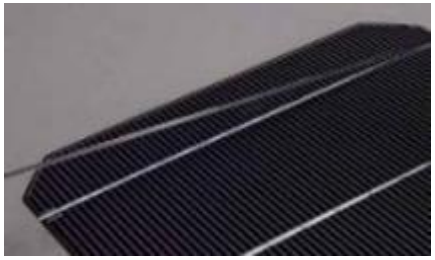


Ribbon + LRF



Ribbon cross-section





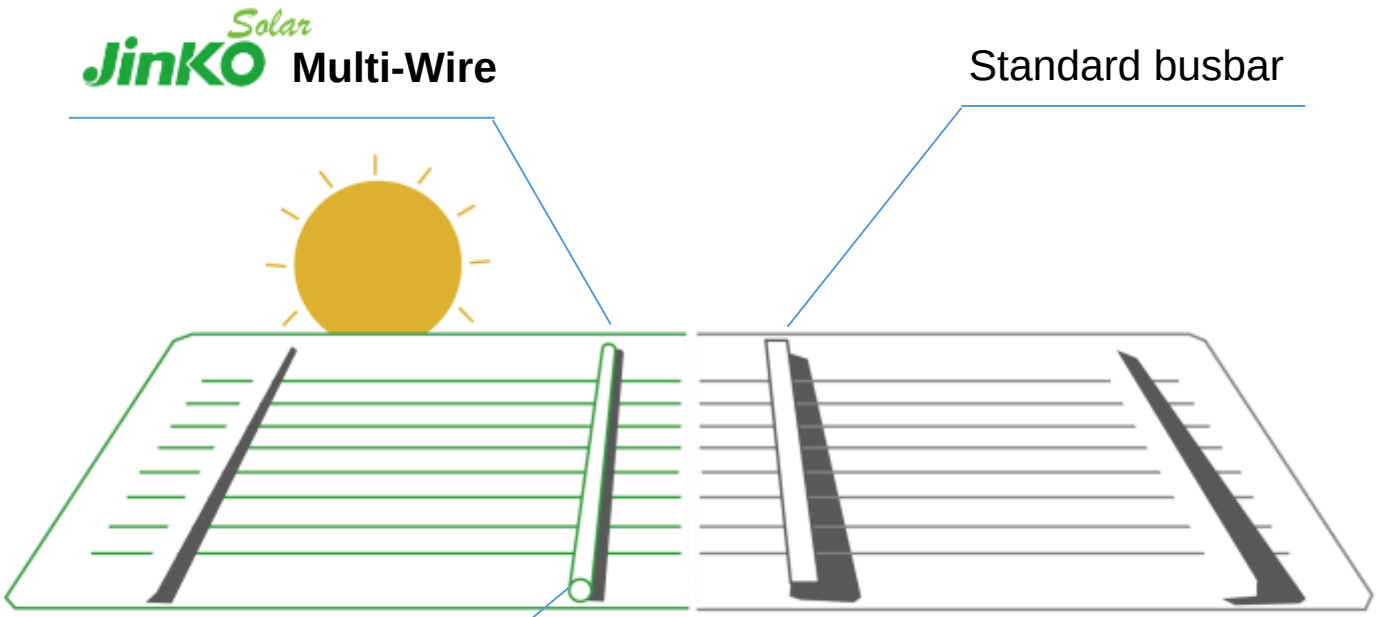
LRF cross-section

Boosted light utilization at modul level thanks to higher internal reflections

Module power output increased by more than 3W

Thicker EVA alleviates internal stress

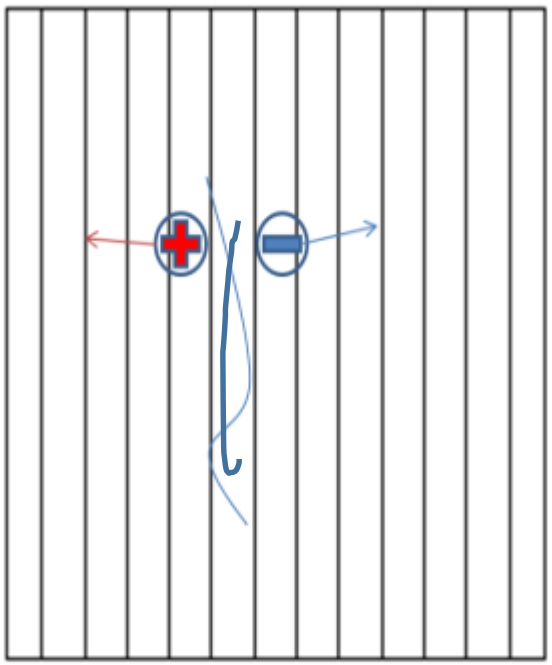
Multi-Wire: Reduced Shading Effect



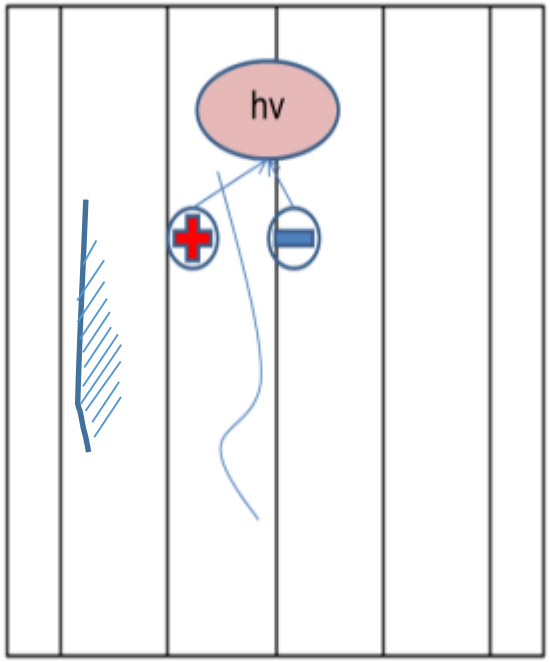
Reduced shading through wire cell interconnection for more output

MBB: Less Sensitive to Micro-Crack

MBB



Normal Busbar



Short distance between Busbar leads less micro-crack

Mono PERC: Key Module Features & Benefits

The most cost-effective C-Si high-eff. leading technology

- Highest Efficiency, boosted yield

Available at multi-gigawatt scale industrial production

- Mature production process

Mature technology and long track record

- Bankable globally

Well understood LID stabilization solution

- High long-term reliability

Long-term established QA protocols and continuous R&D studies

- Potential for further efficiency and reliability increase

Half-cell: Key Module Features & Benefits

Lower resistive losses

- Higher Wp, higher yield, lower LCOE, higher IRR

Better Temp.Coeff.

- Higher performance in hot environment conditions

Split-cells in parallel

- Lower mismatch losses due to soiling, shading, cracks etc.

Lower Imp

- Hot-spot effect mitigation

Split Junction-Box

- Improved heat dissipation design

MBB: Key Module Features & Benefits

Lower Losses

- Higher Wp

More Internal Reflection from Round Ribbon

- Power gain

Less Sensitive to Micro-crack

- Higher reliability

Lower cell shading effect

- Better light utilization

Thinner wire design

- Better Aesthetic

Bifacial: Key Module Features & Benefits

Bifacial cell structure

- Double light collecting ability, higher power and energy yield

High Bifacial Factor

- Rear side efficiency higher than 15.5%, bifacial factor higher than 0.70 (P-type)

High Durability and Reliability

- Dual-glass durable encapsulation, high PID-resistance, 30y Warranty

1500V system voltage

- Longer strings, lower BOS costs

Frameless design

- Suitable for BIPV or other applications